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**Academic motivation mediates the influence of temporal discounting on
academic achievement during adolescence**

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Abstract

This study used a large sample ($N=638$) of 12-18 year old adolescents to investigate the relationship between academic achievement and temporal discounting, a behavioural measurement of delay of gratification abilities. Neuroscience studies have demonstrated development during adolescence of the areas of the brain involved in delaying immediate gratification in order to achieve long-term goals. This finding may have important consequences for educational practice, as students are frequently required to forsake attractive short-term rewards in favour of less attractive academic long-term alternatives. Results showed that adolescents with an increased ability to delay gratification achieved higher grades than those less able to delay gratification. This relationship was mediated by academic motivation, showing that the effect of delayed gratification abilities on grades was most effective when academic motivation was high. Our results show that the ability to delay gratification may be an individual difference variable that distinguishes high achieving students from their peers. It also highlights that understanding the development of neurocognitive processes can provide a valid contribution to understanding ways in which we can influence academic success.

Keywords: Temporal discounting, Delay of gratification, Academic achievement, Motivation, Adolescence, Educational Neuroscience

1. Introduction

The ability to delay gratification is particularly important in educational contexts, as education is by nature a future-oriented investment. Rewards in educational settings, such as getting a good grade after studying for an exam, are often days or weeks away. Therefore, adolescents are continually faced with decisions that require them to choose between attractive non-academic pursuits with immediate rewards (e.g. going out with friends), or delaying gratification in favour of the long-term dividends offered by engaging in academic activities.

Functional neuroimaging studies in adults have repeatedly shown that two competing neural networks are activated when individuals make intertemporal choices between immediate and delayed rewards (Ballard & Knutson, 2009; McClure, Ericson, Laibson, Loewenstein, & Cohen, 2007). Activation of a limbic network including the ventromedial prefrontal cortex and ventral striatum, which mediates reward sensitivity, has been shown to predict preferences for small immediate rewards. Activation of a network of lateral prefrontal and parietal areas related to higher order cognitive control is associated with choosing larger delayed rewards (McClure, Laibson, Loewenstein, & Cohen, 2004). This has led to the suggestion that when delaying gratification, activity in prefrontal and associated areas may be required to override the impulsive drives of the limbic system. However, during adolescence, these cognitive control abilities have not fully matured, as a result of continued structural and functional development of the brain areas involved (De Luca, et al., 2003; Giedd, 2004; Giedd, et al., 1999; Gogtay, et al., 2004; Luciana, Conklin, Hooper, & Yarger, 2005). Combined with studies showing that reward related areas in the brain are more responsive in adolescents compared to adults (Ernst, et al., 2005), these neuroscientific insights suggest that adolescence may be a developmental period

characterised by immature levels of the cognitive abilities required to delay gratification, combined with an increased sensitivity to immediate rewards. As delay of gratification abilities are vital in educational settings, this may result in long-term consequences for adolescent academic achievement.

In the field of neuroscience, delay of gratification has been investigated through use of temporal discounting paradigms, which measure the decline in subjective value of a future reward as the time between the decision and delivery of the reward increases (McClure, 2007; Wittman, Leland, & Paulus, 2007). The behaviour of individuals with a high rate of delay discounting is strongly influenced by a preference for immediate rewards, rather than by the pursuit of long-term goals. Hence for these individuals, when the consequences of actions are delayed, they decrease in value and as a result are less effective in guiding current choices. The choice made by a student when encountering, for instance, the decision between going to the cinema with friends, or staying at home and studying for a test, will depend on the manner in which the individual views on these two options. Some students may choose to study only when the delay to the reward (i.e. a good grade on the test) is short. Others may be more able to delay their desire for the immediate gratification of seeing the film and consequently choose to study even if it requires a substantial and prolonged effort to enable them to receive a distant reward (Silva & Gross, 2004).

Discount rates decrease with age from childhood through to adulthood, as preferences for immediate rewards decrease (Green, Myerson, & O'Staszewski, 1999; Olson, Hooper, Collins, & Luciana, 2007; Steinberg, et al., 2009). A recent study by Chrisakou et al. (2011) investigated the neural maturation that accompanies this. They found that the previously observed age-related decrease in impulsive choices during

adolescence, were associated with changes in activation in the limbic corticostriatal network in the brain, including the ventromedial prefrontal cortex. Research by Olson and colleagues (2009) has also shown that developing connectivity between networks in the brain is an important influence on discounting behaviour. They demonstrated that discounting behaviour was related to the integrity of the white matter pathways that interconnect the lateral prefrontal and temporal/parietal cortices in participants aged 9 to 23 years. Increases in connectivity between these areas resulted in lower rates of temporal discounting. Interestingly, some of the reported associations were age-dependent, meaning that they likely reflect developmental processes, while others, particularly in the left temporal and right frontal regions, were age-independent. The authors speculate that these age-independent associations may reflect individual differences in discounting behaviour, for example due to differences in behavioural functioning such as impulsivity or aggression.

The described findings clearly suggest that temporal discounting abilities are still developing during adolescence. Their influence on academic achievement however has not been studied in detail in this age-group, despite the relevance of these abilities to the decisions adolescents frequently make in academic situations. The relationship between discounting behaviour and academic achievement has been examined in other samples. Research in adult samples has shown that a preference for immediate rewards is related to lower levels of lifetime educational attainment (De Wit, Flory, Acheson, McCloskey, & Manuck, 2007; Reimers, Maylor, Stewart, & Chater, 2009). A classic study, by Mischel, Shoda and Rodriguez (1989) demonstrated that children who were able to delay gratification at the age of four, achieved better academically during adolescence than their less patient peers. Kirby, Winston and Santiesteban (2005) used a delay discounting task to investigate the

relationship between the discount rates and grade point averages (GPA) of undergraduate college students. They found that GPA was significantly correlated with discount rates, with grades decreasing as less weight was placed on future rewards. Silva and Gross (2004) demonstrated this relationship is not domain specific, by finding that the highest achieving college students in their sample were less oriented towards immediate monetary rewards, as well as electing to do more extra credit work than their lower scoring counterparts. These studies suggest that discounting behaviour may be an individual difference variable that distinguishes the highest achieving adolescents from their peers. This relationship has not been examined during the adolescence, despite neuroscientific evidence showing that this is an important period in the development of discounting abilities.

Furthermore, the mechanism through which discounting behaviour affects academic achievement has not yet been examined. Studies in the domain of educational science however, suggest that a possible mechanism may be through academic motivation (De Volder & Lens, 1982; Phaet, Andriessen, & Lens, 2004). Academic success requires effort in the short-term to generate greater rewards in the long-term. Students who are able to delay gratification will be able to make decisions aimed at attaining their long-term educational goals, thereby forsaking attractive short-term alternatives. This increased attention to the future is likely to lead to increased levels of the academic motivation to achieve these long-term educational goals, by enabling the students to consistently make the decisions required to meet them. Educational research has explored this idea through research into the concept of 'future time perspective.' Though defined differently by different researchers, the term is generally used to refer to integration of the future into the present through the setting of goals in the present to attain these in the future (Husman & Lens, 1999). In

contrast to discounting research, which measures decision-making at a behavioural level, future time perspective has been assessed with a variety of methodologies including self-report questionnaires. (De Volder & Lens, 1982; Husman & Lens, 1999; Lens & Decruyenaere, 1991). Future time perspective has been shown to explain a small but significant amount of variance in individual's discounting performance, suggesting that it is one of multiple factors that contribute to discounting behaviour (Steinberg, et al., 2009). Moreover, it has previously been found to predict school investment (Peetsma, 2000) and academic motivation. Therefore, in this study we were interested in the influence of academic motivation on the relationship between discounting behaviour and academic achievement.

In summary, neuroscience research suggests that adolescence is a vital period in the development of delayed gratification abilities that influence decision-making in educational contexts. We presume that pupils who are able to delay gratification are likely to achieve higher grades, possibly through increases in their academic motivation as they strive to realise their long-term academic goals. Therefore, this study examined the mediating effect of academic motivation on the relationship between discounting behaviour and academic achievement. A large cross-sectional sample ($N = 638$) of Dutch secondary school students completed a temporal discounting task in combination with a questionnaire examining their academic motivation. A measure of academic achievement was also obtained. We hypothesise that there is a negative relationship between discounting and academic achievement, i.e. that higher academic achievement is associated with lower discounting and vice-versa. Furthermore we presume that this relationship is partially mediated by academic motivation. Students who are better discounters will be more motivated and therefore achieve better academically.

2. Method

2.1 Participants

The participants were secondary school students between the ages of 12-18 years ($M = 15.01$, $SD = 1.68$, 44.4% male), recruited within a large-scale, cross-sectional study of cognitive development during adolescence. Of the 696 adolescents in the original sample, 670 met the criteria for the current study. All participants included in this study were enrolled in either senior general secondary education (*Hoger Algemeen Vormend Onderwijs* or ‘havo’) or pre-university education (*Voorbereidend Wetenschappelijk Onderwijs* or ‘vwo’). These constitute the two highest levels of education within the Dutch secondary school system and approximately 40% of pupils are enrolled in one these levels (Ministerie van Onderwijs, 2009). Participants were recruited from four schools in the Maastricht region in the south of the Netherlands. To be included in the study participants had to be typically developing with no prior history of neurological, psychological and/or psychiatric disorders such as ADHD or autism spectrum disorders.

2.2 Procedure

Participants were recruited through schools. Students in participating classes were given a short presentation by the researchers about the general aims of the research project. Following the presentation they received an information package to take home. Students who wished to participate were asked to return the enclosed consent form. Additionally, their parents were asked to complete a questionnaire regarding their child’s medical history and educational background, which was returned with the consent form. Participating students constituted 38% of the initial sample.

Data collection took place in the participating schools during normal class time and was supervised by the classroom teacher and two trained psychologists. The classroom teacher gave non-participating students an alternative task to work on in silence whilst testing took place. Completion of all tasks and questionnaires took approximately 40 minutes, of which approximately 10 minutes were spent on the task and questionnaire included in this study. All questionnaires were checked following completion. If missing values were found participants were subsequently asked to complete these items.

The VU University Amsterdam institutional ethical review board approved all procedures. Participation was voluntary and written informed consent was obtained from both participants and their parents prior to inclusion in the study.

2.3 Measures

2.3.1. Demographics: by means of a parental questionnaire information was gathered about participants' age, medical history and educational background. This was used to identify participants in the sample who did not meet the inclusion criteria for the current study.

2.3.2. Delay discounting: participants completed a paper and pencil version of a delay discounting task based on the procedure used by Rachlin, Raineri and Cross (1991). The task required choices to be made between a hypothetical, fixed delayed reward of €50 and a smaller, hypothetical immediate reward. The immediate rewards ranged from €5 to €45 and increased in €5 increments. Three delay intervals were used: 1 week, 1 month and six months. Participants completed items separately for each of the three delay intervals and in ascending order. As Green, Myerson and McFadden

(1997) have shown, the rate of temporal discounting is influenced by reward magnitude. Therefore the amounts selected for use in the task were close to amounts adolescents could realistically receive, thereby reflecting real-life decisions.

Responses were used to determine each individual's *indifference point* for each of the three delay intervals, defined as the item where participants switched from selecting the delayed reward to selecting the immediate reward. After this point the smaller immediate reward is preferred over the larger delayed reward. The higher the indifference point, the better an individual's abilities to delay gratification.

2.3.3. Academic motivation: Academic motivation was measured using the motivation subscale of the Dutch Schoolvragenlijst (School Attitude Questionnaire, or 'SAQ'; Smits & Vorst, 1998), a psychometrically sound and well-accepted diagnostic tool in the Dutch educational system. The subscale measures motivation for schoolwork, ability and willingness to concentrate in class and attitude towards homework. It consists of 24 self-report items scored on a 3-point scale: agree, don't agree, unsure. Sample questions include "*I work hard in all subjects to get good grades*", "*I pay attention when my teacher explains something to me.*"

2.3.4. Academic achievement: Participants' end-of-year grades for three subjects, Dutch (native language), English (foreign language) and Maths, were combined to create a single measure of academic achievement. These subjects are compulsory for all students from the first through to their final year of secondary school. Furthermore they have been shown to be valid estimators of school performance (Reed, Ouwehand, van der Elst, Boschloo, & Jolles, 2010). End-of-year grades were used as

these incorporate results from multiple exams taken by students throughout the school year.

As participants were recruited from four different schools, we assumed there would be differences in grading policies. Therefore, grades were averaged into z-scores based on the mean grade and standard deviation of each individual school. This resulted in similar distributions of grades for each school as well as correcting for any differences in grading policies.

2.4 Analyses

All analyses were performed using PASW Statistics 17.0 for Mac. The area under the discounting curve (AUC) was used to calculate a measure of overall discounting behaviour. The AUC method is a frequently used (e.g. Dixon, Marley, & Jacobs, 2003; Olson, et al., 2007; Scheres, et al., 2006), theoretically neutral measure, which avoids the difficulties involved in using theoretical discounting functions to interpret discounting data (Myerson, Green, & Warusawitharana, 2001). Each delay interval was recalculated as a proportion of the maximum delay used in the task (i.e. six months) and the value of the various indifference points were recalculated as a proportion of the maximum delayed reward (i.e. €50). These normalised data points were plotted and vertical lines were drawn from each of the three data points on the discounting curve to the x-axis, thereby creating three trapezoids. The sum of the areas of these trapezoids was then computed. Due to the normalisation of the data points this area ranges between 0.0 and 1.0, with higher values indicating less discounting.

All effects are reported as significant at $p < .05$. Age was included in all analyses as a covariate, as age has been shown to influence both discounting

(Steinberg, et al., 2009) and academic motivation (Peetsma, Hascher, van der Veen, & Roede, 2005). To investigate the relationship between discounting behaviour and academic achievement a multiple regression analysis was performed, using academic achievement as the outcome measure. The first block contained age and the second block contained the AUC, thereby examining the effect of AUC after controlling for age. This analysis formed the first of three regression analyses required for the examination of the hypothesised mediating effect of academic motivation. This was examined using Baron and Kenny's (1986) framework for mediation analysis. In the case of our model this framework required that the following assumptions be met: 1) a significant effect of AUC on academic achievement, 2) a significant effect of AUC on academic motivation, 3) a significant effect of academic motivation on academic achievement and 4) when AUC and academic motivation were included in the same regression analysis, the effect of AUC on academic achievement should have been less than the effect of AUC on academic achievement when academic motivation was not controlled for. Therefore, in addition to the regression analysis described above, a multiple regression analysis was performed with academic motivation as the dependent variable, age as a covariate and AUC as an independent variable (assumption 2). This was followed by a third multiple regression analysis with academic achievement as a dependent variable, age as a covariate and AUC and academic motivation as independent variables (assumptions 3 and 4). In all analyses age was entered in the first block and the other independent variables were entered in the second block. In the case of multiple variables simultaneous forced entry was used. Finally, a Sobel test was used to test the significance of the effect of AUC on academic achievement through academic motivation.

3. Results

3.1. Validity of discounting data

Prior to analysis participants' discounting data was checked for inconsistencies. Inconsistent discounting was defined as an increase in the subjective value (i.e. indifference point) of the delayed reward as time increased. In line with previous studies (Olson, et al., 2007; Reynolds, Ortengren, Richards, & de Wit, 2006) inconsistent discounters ($N = 32$) were excluded from further analyses. Following exclusion of inconsistent discounters the sample consisted of 638 participants. Analyses showed that consistent and inconsistent discounters did not differ with regards to age, sex or level of education.

3.2 Relationship between discounting behaviour and academic performance

Table 1 shows the outcome of the multiple regression analysis, with academic achievement as an outcome measure. Step 1 included just the covariate, age. Results showed that age was not a significant predictor of academic achievement. Step 2 showed that adding AUC to the model increased the predictive power of the model, which predicted 2.1% of the variance in grades, showing that the more students discounted the value of future rewards, the better their academic achievement. Furthermore it confirmed the presence of a significant relationship, hereby meeting the first assumption of mediation analysis.

Insert Table 1 about here

3.3 Mediating effect of motivation

A two-step hierarchical regression analysis showed that both age and AUC were significantly related to academic motivation ($R^2 = .031$; Age: $B = -.132$, $SE(B) = .031$, $\beta = -.167$; $p < .01$; AUC: $B = .412$, $SE(B) = .204$, $\beta = .080$; $p = .044$). This confirmed the second assumption of the mediation analysis. The subsequent regression analysis, examining the predictive value of AUC and academic motivation in a single model showed that both AUC and motivation were significant predictors of academic achievement (see Table 2), thereby meeting the third assumption. Furthermore, the effect of AUC was decreased, suggesting that motivation had indeed mediated the relationship between AUC and academic achievement (assumption 4). A follow-up Sobel test indicated that this mediation effect was significant (Sobel test-statistic = 1.931, $p = .05$). The mediation model is shown in Figure 1.

Insert Table 2 and Figure 1 about here

4. Discussion

The present study investigated the relationship between temporal discounting and academic achievement in a large sample of Dutch secondary school students. We hypothesised that higher academic achievement would be associated with lower levels of temporal discounting. Furthermore, we assumed that this relationship was mediated by academic motivation.

Our results confirmed our hypothesis that students with lower levels of temporal discounting perform better academically. The area under the discounting curve was significantly related to academic achievement and was associated with 2.1% of the variance in grades. Lower levels of discounting were also associated with higher levels of academic motivation, indicating that an increased ability to delay gratification was related to increased academic motivation. Furthermore, the results of

multiple regression and mediation analyses supported our hypothesis that academic motivation mediated, albeit partially, the relationship between discounting behaviour and academic achievement. The final regression model predicted 8.6% of the variance in academic achievement, with 6.7% being accounted for by motivation and 1.6% by discounting. This indicated that the variance attributed to discounting behaviour decreased when academic motivation was added to the model, due to motivation explaining a proportion of the variance in academic achievement accounted for by discounting behaviour.

The amount of variance in end of term grades predicted by delay discounting performance in our study was relatively low, with the variance in area under the discounting curve predicting 2.1% of the variance in grades. Nevertheless, this is, as Kirby et al. (2005) have noted, still a considerable proportion when all other factors that can influence both discounting and academic achievement are considered. Previous research has shown that discount rates fluctuate with reward magnitude, reward type and method of administration (Estle, Green, Myerson, & Holt, 2007; Kirby & Marakovic, 1996; Smith & Hantula, 2008), while academic achievement is influenced by a multitude of factors such as cognitive ability, personality and level of parental support (Fan & Chen, 2001; Laidra, Pullmann, & Allik, 2007; Rivkin, Hanushek, & Kain, 2005). It seems unlikely that discounting behaviour, as was examined in this study, could predict a large component of variance in a variable that is influenced by so many other factors. Nonetheless, the growing number of studies finding a relationship between discounting behaviour and academic achievement indicate that discounting behaviour is a small but consistent influence on academic success (Kirby, et al., 2005; Silva & Gross, 2004). Furthermore, our finding of a significant association in our adolescent sample between levels of temporal

discounting and academic performance confirms that this influence is present both in adolescents of secondary school age as well as in the older samples, consisting of college students, examined in these previous studies.

Our findings are relevant in various educational contexts. At times students will encounter learning environments that they do not find intrinsically interesting and which require them to complete academic tasks they do not enjoy. It is in these situations that the ability to resist the lure provided by non-academic sources of instant gratification becomes especially important, with students who are unable to resist these temptations being at risk of not realising their full academic potential. This is especially so during adolescence, when the ability to delay gratification is still developing (Christakou, et al., 2011; Steinberg, et al., 2009). Developing methods of identifying decreased abilities to sacrifice short-term pleasure in favour of long-term academic gain may therefore prove to be increasingly important in improving academic motivation and achievement during adolescence. Schools could subsequently use this knowledge to stimulate these underdeveloped abilities, for example through teaching goal-setting strategies encouraging students to work towards long-term rewards. Previous research in children has suggested that self-control abilities are malleable and can be improved over time (Diamond & Lee, 2011). Alternatively, schools could choose to work with their students' preferences for the short-term by offering them immediate incentives, such as money or tokens, related to their academic performance (e.g. Marinak & Gambrell, 2008). The latter option is controversial and many researchers have suggested that it should only be used in combination with carefully chosen incentives and conditions to prevent undermining intrinsic motivation (Cameron, 2001; Deci, Koestner & Ryan, 2001). However, research showing that a decreased ability to delay gratification is associated

with increased substance dependence, lower income and increased health problems (Moffitt, et al., 2011; Reimers, et al., 2009), implies that these decreased abilities could place individuals at a life-long disadvantage. Programmes aimed at stimulating healthy development of delay of gratification abilities may therefore be preferable when considering the long-term implications.

Certain limitations to the present study must be considered when interpreting the current findings. First, it could be argued that, as the rewards used in our discounting task were both monetary and hypothetical, the task does not measure 'real-life' behaviour that bears a direct relation to academic achievement. However, previous comparisons of tasks using real and hypothetical rewards have shown no differences between the results found (Johnson & Bickel, 2002; Madden, Begotka, Raiff, & Kastern, 2003). Furthermore, research comparing a monetary and academic discounting task within a single sample found similar results across both types of tasks (Silva & Gross, 2004). Second, the sample used in this study consisted of students enrolled in relatively high levels of education, which would enable them to enter higher educational at college or university level. These students are generally more motivated than their peers enrolled in lower levels of education (Peetsma, et al., 2005). This suggests that if the study were replicated using less highly educated samples discounting preferences may be able to influence their lower levels of motivation to a larger degree than in our relatively highly motivated sample.

In summary, our results have shown that students' discounting behaviour directly influences their academic achievement. This relationship is partially mediated by academic motivation, with lower rates of delay discounting leading to increased motivation to learn, which in turn increases academic achievement. Furthermore, we have demonstrated that insights from the domain of neuroscience about adolescent

temporal discounting can be used to explain processes influencing academic achievement. Together with insights from the domain of educational science about academic motivation, this provides a more extensive explanation of the studied phenomenon than either domain singularly and emphasises the added value of bringing together different research traditions.

Table 1

Regression model with academic performance as outcome measure

	B	SE (B)	β
Step 1			
Age	-.008	.018	-.017
Step 2			
Age	-.017	.018	-.037
AUC	.441	.120	.145**
<i>Note.</i> $R^2 = .000$ for Step 1 (ns), $\Delta R^2 = .021$ for Step 2 ($p < .01$). * $p < .05$, ** $p < .01$.			

Table 2

Final regression model with academic performance as outcome variable

	B	SE (B)	β
Step 1			
Age	-.008	.018	-.017
Step 2			
Age	-.017	.018	-.037
AUC	.378	.117	.125**
Motivation	.152	.023	.259**
<i>Note.</i> $R^2 = .000$ for Step 1 (ns), $\Delta R^2 = .086$ for Step 2 ($p < .01$). * $p < .05$, ** $p < .01$.			

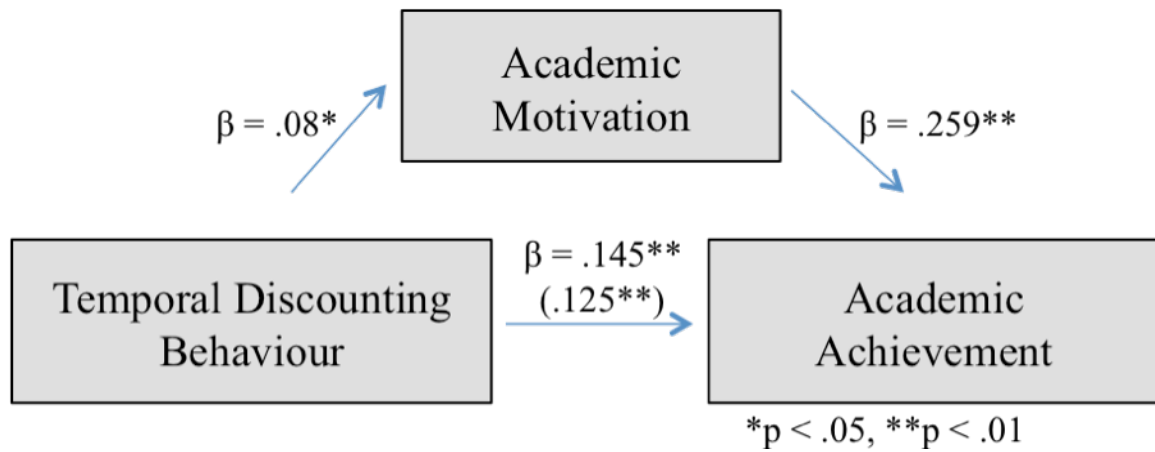


Figure 1. The examined mediation model. The standardised regression coefficient between discounting behaviour and academic achievement controlling for academic motivation is in parentheses.

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